Air Pollution and Unscheduled Hospital Outpatient and Emergency Room Visits

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We conducted a time-series analysis of daily hospital visits and air pollution data to assess acute effects of air pollution on daily unscheduled outpatient visits to internal medicine, pediatric, and emergency departments in the No. 3 Affiliated Hospital of Beijing Medical University in Beijing, China. Sulfur dioxide was marginally significantly associated with total outpatient visits (ß = 41.5, SE = 24.2) and significantly associated with internal medicine (ß = 14.6, SE = 6.7), pediatric (ß = 12.7, SE = 3.7), and emergency room visits (ß = 6.8, SE = 2.7). Total suspended particulates (TSP) was a significant predictor for total outpatient (ß = 21.1, SE = 7.7) and pediatric visits (ß = 3.4, SE = 1.3) and a marginally significant predictor of internal medicine visits (ß = 4.2, SE = 2.2). In a season-specific analysis, SO_2 was a significant predictor for total hospital outpatient visits in summer, although the mean daily SO_2 concentration was only 17 $\mu g/m^3$ (maximum = 51 $\mu g/m^3$). In winter, SO_2 was significantly associated with internal medicine, pediatric, and emergency room visits, and TSP was associated with total outpatient visits. This study suggests an exposure–response relationship between TSP and SO_2 and hospital outpatient visits, both at high air pollution levels and at levels well below air quality standards recommended by the World Health Organization. Key words: emergency room visits, outpatient visits, sulfur dioxide, total suspended particulates. *Environ Health Perspect* 103:286–289 (1995)

Increased particulate and sulfur dioxide concentrations have been associated with excess daily mortality (*1–4*), hospital admissions (*5*), and emergency room visits (*6–8*). However, few studies have been conducted to assess the effect of air pollution on daily office visits to physicians because regular outpatient visits in the United States are scheduled by appointment.

The 1989 Health Statistics of China (*9*) reports that annual total deaths in China were about 6.6 million, annual hospital admissions about 50.9 million, and annual physician office visits and emergency room visits about 2.4 billion. Therefore, mortality and hospital admissions can detect only a small proportion of the population potentially affected by air pollution. In contrast, physician office visits yield greater coverage by including less severe cases and thus confer a greater power to detect health effects of air pollution.

In China, regular hospital outpatient visits to doctors are unscheduled. Data on daily outpatient and emergency room visits collected from the No. 3 Affiliated Hospital of Beijing Medical University in Beijing provide an opportunity to examine the acute effects of air pollution on hospital outpatient visits. The exposure–response relations were also examined in low (summer) and high (winter) pollution seasons.

Methods

The No. 3 Affiliated Hospital of Beijing Medical University is located in the northwest part of Beijing. There are no major manufacturing industries in the area. Bicycles are the primary form of transportation. Automobile, bus, and commercial traffic is light on most streets. Coal stoves used for heating and cooking in households are the major air pollution source. Few homes are air conditioned, and windows are kept open during the summer.

Before seeing a physician, all patients must register and pay a registration fee in the hospital reception department. Data for the 1990 calendar year were obtained from the hospital reception department, which is in charge of the patients' registration and referrals. The major departments in the No. 3 Affiliated Hospital of Beijing Medical University include surgery, pediatrics, internal medicine, obstetrics and gynecology, orthopedics, dermatology, neurology, ophthalmology, ear-nose-throat, stomatology, and Chinese traditional medicine. The hospital is open regularly all day on Monday, Tuesday, Thursday, and Friday, plus Wednesday and Saturday mornings. Patients can see doctors on Sunday, Wednesday afternoon, and Saturday afternoon by paying a higher registration fee. There were 7 holidays in 1989, January 1 (New Year), January 27, 29, and 31 (Chinese New Year), May 1 (International Labor Day), and October 1 and 3 (National Day), during which only emergency rooms are open.

Total suspended particulate (TSP) and SO_2 concentrations are measured at the World Health Organization Global Air Monitoring Stations located in Xichen and Dongchen (residential areas). The average values of the monitoring data from the two areas were used to represent the Beijing residential area concentrations. TSP is measured gravimetrically and SO_2 is measured by colorimetric pararosaniline methods (*10*). Daily air samples are collected and analyzed for 2–3 weeks each month starting with the second week of the month. Temperature and humidity data were obtained from Beijing Weather Bureau.

A frequency plot of daily hospital outpatient and emergency room visits suggests a normal distribution. Daily outpatient visits were regressed by linear regression, with a Markov correction for the autocorrelation in time-series data (*11*). Using a generalized additive modeling technique, we first produced smoothing plots to determine the functional dependence between daily hospital and emergency room visits and the covariates including air pollution concentration, temperature, and humidity without imposing a rigid parametric assumption about that dependence (*12,13*). We then estimated the regression coefficients using a quasi-likelihood approach (*11*) with robust estimates of variances (*14*). Because the model included outpatient visits from previous days, the estimated coefficients for air pollution represent the effects conditioned on the previous days' visits.

Results

Table 1 shows the distribution of air pollution, weather, and daily hospital outpatient visits in Fuxing Hospital in 1990. TSP measurements were available for 212 days (mean 387 $\mu g/m^3$, maximum 1255 $\mu g/m^3$) and SO_2 measurements for 208 days (mean 118 $\mu g/m^3$, maximum 478 $\mu g/m^3$). The average daily hospital outpatient visits were 1836, of which 169 and 347 patients visited the pediatrics and internal medicine departments, respectively. The average daily emergency room visits were 182.

Locally weighted regression, including temperature, humidity, day of the week, and the time variable plus SO_2 or TSP (Fig. 1), showed a positive association between daily hospital visits and air pollution and suggested a linear association between daily hospital outpatient visits and both SO_2 and TSP, after adjustment for all other covariates. The other covariates showed nonlinear dependence with daily hospital visits and were therefore modeled as indicator variables in the final regression models.

Models including SO_2 and TSP were fit separately. Air pollution effects were expressed as the increase in the number of outpatient or emergency room visits for each 100 $\mu g/m^3$ increase in SO_2 or TSP (Table 2). SO_2 was significantly associated

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Table 1. Distribution of weather, air pollution, and physician office visits in Fuxing, Beijing, 1990

Variable	Mean	SD	Min	Max
Weather (n = 365)[a]				
Temperature (°C)	13	11	-10	30
Humidity (%)	59	20	10	99
Air pollutants (μg/m^3)				
TSP (n = 212)	387	199	106	1255
SO_2 (n = 208)	118	133	6	478
Outpatient and emergency room visits (n = 358)				
Total outpatient	1836	752	182	3129
Pediatrics	169	60	43	322
Internal medicine	347	158	27	673
Emergency room	182	44	89	516

TSP, total suspended particulates.
[a]Number of days measured.

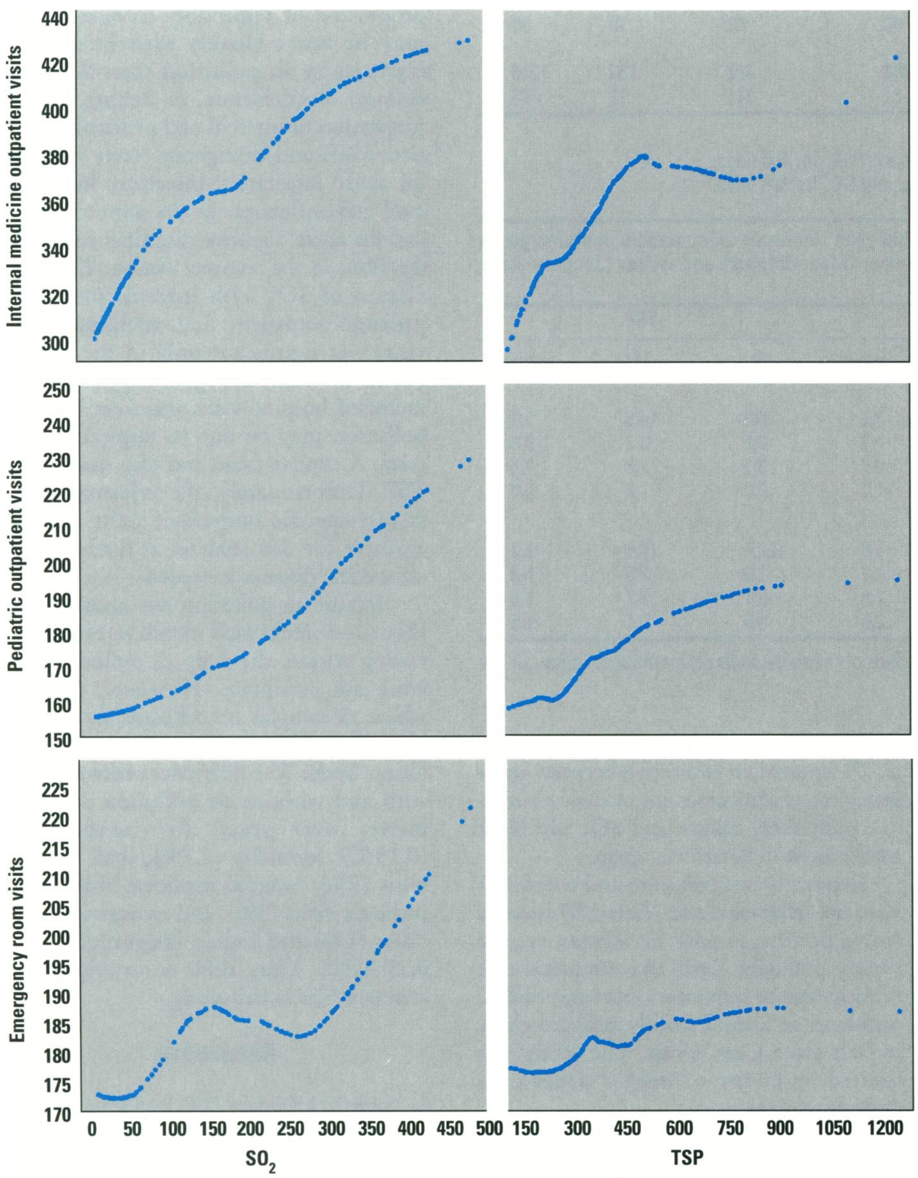

Figure 1. Locally weighted regression smoothing plots of internal medicine, pediatrics, and emergency room visits with SO_2 and total suspended particulates, with use of generalized additive modeling approach to control for temperature, humidity, day of the week, and seasons.

with internal medicine (ß = 14.6, SE = 6.7) and pediatric outpatient (ß =12.7, SE = 3.7) visits and emergency room visits (ß = 6.8, SE = 2.7) and marginally significantly associated with total outpatient visits (ß = 41.5, SE = 24.2). TSP was a significant predictor for total outpatient visits (ß = 21.1, SE = 7.7) and pediatric visits (ß = 3.4, SE = 1.3) and a marginally significant predictor of internal medicine visits (ß = 4.2, SE = 2.2).

SO_2 and TSP concentrations were much lower in the summer than in the winter (Table 3). Of note, the mean daily SO_2 concentration was only 17 μg/m^3 (maximum = 51 μg/m^3) during the summer. A season-specific regression analysis was performed, with adjustment for temperature, humidity, and day of the week. SO_2 was a significant predictor for total hospital outpatient visits in the summer and for internal medicine and pediatric outpatient visits and emergency room visits in the winter (Table 4).

Because air samples were collected and analyzed for about 2–3 weeks of each month at each monitoring station, the daily air pollution data were not complete. However, days on which air samples are collected are selected at random and are independent of air pollution levels. The p-values for testing the difference in temperature, humidity, total outpatient visits, internal medicine visits, pediatric visits, and emergency room visits between days with and without complete air pollution measurements were 0.69, 0.83, 0.68, 0.99, 0.36, and 0.27, respectively, showing no appreciable selection bias.

Discussion

The present study analyzed the medical records obtained from the No. 3 Affiliated Hospital of Beijing Medical University and found a significant association of air pollution with unscheduled hospital outpatient visits and emergency room visits. These results are consistent with the findings from the previous studies in Beijing (*4,15–17*). A cross-sectional analysis of random samples of Beijing adults who never smoked, 40–69 years old, indicated that chronic exposure to high concentrations of TSP and SO_2 was associated with increased prevalence of respiratory diseases (*15*) and reduced pulmonary function (*16*). Two recent studies conducted in residential areas of Beijing found that increased air pollution levels were associated with daily mortality (*4*) and hospital outpatient visits (*17*). These studies provide coherent evidence on adverse health effects of current air pollution levels in Beijing and suggest that air pollution in Beijing needs to be better controlled.

The acute effects of air pollution on hospital admissions and emergency room visits have been evaluated in a number of previous

Table 2. Estimated effects of SO_2 and total suspended particulates (TSP) for each 100 μg/m^3 increase on outpatient and emergency room visits from linear regression[a]

	SO_2			TSP		
Hospital service	ß	SE[b]	*t*-value	ß	SE	*t*-value
Total outpatient	41.5	24.2	1.7	21.1	7.7	2.8
Internal medicine	14.6	6.7	2.2	4.2	2.2	1.9
Pediatrics	12.7	3.7	3.5	3.4	1.3	2.6
Emergency room	6.8	2.7	2.5	1.1	0.8	1.4

[a]The model adjusted for quintiles of temperature, quintiles of humidity, indicator variables of day of the week, and seasons.
[b]Standard errors were estimated by robust method.

Table 3. Mean, minimum, and maximum values of weather, and air pollution in Beijing residential areas, separated by summer (May–October) and winter (January–April, November, and December) seasons

	Summer[a]			Winter[b]		
Variables	Mean	Min	Max	Mean	Min	Max
Weather						
Temperature(°C)	22	11	30	4	-10	19
Humidity (%)	67	20	93	52	10	99
Air pollutants						
TSP (μg/m^3)	289	106	763	486	133	1255
SO_2 (μg/m^3)	17	6	51	211	12	478

TSP, total suspended particulates.
[a]Weather was monitored for 181 days, TSP for 106 days, and SO_2 for 100 days.
[b]Weather was monitored for 177 days, TSP for 106 days, and SO_2 for 108 days.

Table 4. Estimated effects of SO_2 and TSP for each 100 μg/m^3 increase on outpatient and emergency room visits from linear regression, separately by summer (May–October) and winter (January–April, November, and December) seasons[a]

	SO_2			TSP		
Hospital service	ß	SE[b]	*t*-value	ß	SE[b]	*t*-value
Summer						
Total outpatient	570.0	178.6	3.2	20.8	14.5	1.4
Internal medicine	67.3	51.8	1.3	2.8	3.2	0.9
Pediatrics	16.5	23.4	0.7	3.3	2.3	1.5
Emergency room	-27.7	27.7	-1.0	0.0	1.4	0.0
Winter						
Total outpatient	43.1	24.1	1.8	22.6	10.4	2.2
Internal medicine	15.2	6.9	2.2	3.6	2.9	1.3
Pediatrics	8.7	3.1	2.8	3.1	1.7	1.8
Emergency room	6.3	2.5	2.5	1.6	1.1	1.5

[a]The model adjusted for quintiles of temperature, quintiles of humidity, indicator variables of day of the week, and seasons.
[b]Standard errors were estimated by robust method.

studies. Bates and Sizto (*5*) reported that sulfate particulate matter and ozone were associated with hospital admissions in Ontario, Canada. Pope (*18,19*) reported an association between inhalable particles and hospital admissions for respiratory diseases in Provo and Salt Lake City, Utah. Samet and coworkers (*6*) reported associations between both SO_2 and TSP and daily respiratory emergency room admissions in Steubenville, Ohio. Goldsmith and co-workers (*20*) studied a variety of air pollutants and found an important effect of sulfates on daily emergency room admissions from all causes in two areas of Los Angeles with high SO_2. Schwartz and co-workers (*8*) also found that the daily counts of emergency room visits for asthma in patients under 65 years of age were significantly associated with particulate exposure in Seattle, Washington. Sunyer et al. (*7*) reported an association between emergency room admissions for chronic obstructive pulmonary disease and SO_2 and black smoke levels in Barcelona, Spain.

Reports on air pollution and outpatient visits are relatively fewer. Lutz (*21*) found a strong positive correlation between average weekly pollutant levels and the percentage of diagnoses of respiratory tract and cardiac problems at a small family practice clinic in Salt Lake City, Utah. The study was limited by its use of weekly rather than daily outpatient visits.

Two major factors restrict the potential for epidemiologic studies of the acute effects of air pollution on outpatient visits in the United States. First, regular outpatients visits are usually scheduled by appointment. Second, many patients do not visit doctors in local clinics; therefore, outpatient records from a hospital cannot reliably reflect the true morbidity in a given community. The present study takes advantage of China's medical system, where patients seek medical care in their designated local hospitals. Regular outpatient visits are first-come first-served. Thus, the hospital records provide reliable morbidity information for a geographically defined population and offer an opportunity to evaluate the association between daily hospital outpatient visits and air pollution.

A statistically significant relation was found between increased levels of SO_2 and daily hospital internal medicine and pediatric outpatient visits, but not with total outpatient visits. One explanation for this result is that internal medicine and pediatric outpatient visits consisted of a large proportion of respiratory diseases, which may be more closely associated with increases in air pollution than the other diseases. Furthermore, in Beijing, a great proportion of internal and pediatric outpatient visits and emergency room visits are for acute respiratory infection, including cold and influenza, in the winter season, and for acute digestive disorders, including diarrhea, in the summer season. The association of SO_2 with internal medicine, pediatric outpatient, and emergency room visits was significant only in the winter, not in the summer, again suggesting that increased hospital visits associated with air pollution may be due to respiratory diseases. A similar trend was also noticed for TSP. Unfortunately, the information on disease-specific outpatient visits was not available for this analysis. A further study on specific diseases is needed.

Because air pollution was measured for about 2–3 weeks each month in each monitoring station, the daily air pollution data were not complete. However, days on which air samples are collected are selected at random and are independent of air pollution levels. The differences between days with and without air pollution measurements were small for temperature (0.15°C), humidity (2.7%), total hospital visits (3%), internal medicine visits (2%), pediatric visits (3%), and emergency room visits (1%) and highly insignificant (p = 0.27–0.99). Thus, there is no evidence of selection bias in this study.

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